

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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|-------------------------------|---|----------------------------|
| In re Patent Application of |) | |
| |) | |
| Hans OTT |) | Group Art Unit: Unassigned |
| |) | |
| Application No.: Unassigned |) | Examiner: Unassigned |
| |) | |
| Filed: December 7, 2001 |) | |
| |) | |
| For: DEVICE FOR THE PIXEL-BY- |) | |
| PIXEL PHOTOELECTRIC |) | |
| MEASUREMENT OF A PLANAR |) | |
| MEASURED OBJECT |) | |

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Prior to examination of the above-captioned patent application, kindly enter the following amendment.

IN THE ABSTRACT:

Kindly replace the Abstract with the following:

-- The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means for the imaging of the measured object onto a two-dimensional CCD image sensor, filter means provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured, as well as data

processing means for the processing of the raw measured data into image data representing the colors of the individual image elements of the measured object. Furthermore, illumination means are provided which include a Fresnel lens, which illuminate the measured object with at least one essentially parallel light bundle under an angle of incidence of essentially $45^{\circ} + / - 5^{\circ}$. The projection means which include at least one tele-lens constructed as a Fresnel lens, are constructed as tele-central imaging optics, which image each point of the measured object under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle of essentially maximally 5° onto the light converter element array. The data processing means carry out extensive correction measures.

IN THE SPECIFICATION:

Kindly replace the paragraph beginning at page 2, line 22, with the following:

-- It is therefore a further important object of the present invention to provide means for correcting the mentioned interference effects so that the measured data have the precision required for colorimetric applications.--

Kindly replace the paragraph beginning at page 2, line 31, with the following:

-- Preferred embodiments of the invention will be described in the following by way of example only and with reference to the drawings, wherein:

Figure 1 is a schematic illustration of a first embodiment of the measurement device in accordance with the invention;

Figure 2 is a schematic sketch of a spectral video camera of a second embodiment of the measurement device in accordance with the invention;

Figure 3 is a sketch illustrating the geometric rectification of the data of the measured object;

Figure 3A is an enlarged portion of Figure 3;

Figures 4 and 5 show two sketches for illustration of the reflection correction;

Figure 6 is a sketch for illustration of the scattered light correction;

Figure 6A shows an enlarged portion of Figure 6;

Figures 7A and 7B show two test images with respectively one special calibration element;

Figure 8 is a test image with a special scattered light element;

Figure 8A shows the scattered light element of Figure 8 in an enlarged illustration;

Figure 9 is a diagram for the illustration of the calculation of scattered light coefficients; and

Figure 10 is a schematic summary of all correction measures.--

Kindly replace the paragraph beginning at page 4, line 18, with the following:

-- The two flash light sources 4 and 5 are respectively positioned at the focal point of the illumination lenses 42 and 52, so that the measured object M is illuminated with two parallel beam bundles 44 and 54. The positioning is selected such that the angles of incidence α of the two parallel beam bundles are essentially $45^\circ \pm 5^\circ$ to the optical axis of the imaging optics or to the normal 31 of the measured object M. The geometric conditions defined in international standards for the color measurement are thereby complied with.--

Kindly replace the paragraph beginning at page 13, line 3, with the following:

-- The position deviations ΔX and ΔY relative to the normal positions (points 301-309) are determined for each of the nine reference points 311-319 as is apparent from Figure 3a. In the next step, the position deviations for each individual image point of the whole test image are calculated by interpolation from the position deviations of the nine reference points. According to experience, the position deviations of closely adjacent image points are not very different. Thus, according to one aspect of the invention, several, for example 8x8 adjacent image points, are respectively combined into a geometry correction region and the position deviations are calculated only for those geometry correction regions. If one assumes a total of 480 x 640 image points, this results in about $60 \times 80 = 4,800$ regions. The (calculated) position deviations Δx and Δy of those 4,800 geometry correction regions are then saved in a geometry correction table. A portion of an

exemplary geometry correction table is illustrated in Table 3 Δx and Δy values are arbitrary).--

Kindly replace the paragraph beginning at page 13, line 16, with the following:

-- For the geometric correction of the measured object, the geometry correction region to which an image point belongs is determined for each image point (by way of its image point coordinates) and the position deviation Δx and Δy for the respective geometry correction region obtained from the geometry correction table. The actual correction is then carried out in the manner already known in that the measured value of the respective image point is replaced by the measured value of the image point displaced by the position deviation (or by a value interpolated from the surrounding points for non-integer pixel spacings).--

Kindly replace the paragraph beginning at page 13, line 23 (Table 3), with the following:

--Table 3

| Region Number | Image Points | Δx (in pixel) | Δy (in pixel) |
|---------------|-------------------|-----------------------|-----------------------|
| 1 | x1...x8, y1...y8 | 3.25 | -5.75 |
| 2 | x9...x16, y1...y8 | 3.2 | -5.7 |
| And so on | and so on | and so on | and so on |

Kindly replace the paragraph beginning at page 17, line 17, with the following:

-- The scattered light correction for each image point subtracts from the brightness value (remission value) of the respective image point the distance dependent brightness contribution of all image points surrounding the image point. The brightness contribution $\Delta R_{i,j}$ received by an image point i from an image point j is calculated as $\Delta R_{i,j} = k_{i,j} * R_j$. R_j is thereby the remission value of the image point j , and $k_{i,j}$ is a coefficient depending on the distance between the image points i and j , which of course must be determined beforehand. For an arrangement of $N*M$ image points, which are numbered from 1- $N*M$, the contribution of the surrounding points is calculated as follows for each individual image point i :--

Kindly replace the paragraph beginning at page 17, line 26, with the following:

-- The scattered light corrected remission value R'_i is $R_i - \Delta R_i$. As is easily apparent, $(M*M)^2$ coefficients and a corresponding number of multiplications and additions are required for the calculation of the corrections. For 300,000 image points, the required calculation effort would be gigantic and completely impractical as already mentioned.--

Kindly replace the paragraph beginning at page 21, line 11, with the following:

-- Scattered light correction of individual image regions:--

Kindly replace the paragraph beginning at page 21, line 17, with the following:

-- Determination of the scattered light correction coefficients:--

Kindly replace the paragraph beginning at page 23, line 1, with the following:

-- By way of numerous test measurements with scattered light elements of different size, it was found that the scattered light influence decreases at a double logarithmic scale at least in some sections and also overall approximately linear with distance. Figure 9 graphically illustrates in a double logarithmic scale an exemplary relationship between scattered light and image point distance measured by way of 8 scattered light elements. The abscissa shows the distance in pixel units, the ordinate the negative logarithm of the relative scattered light influence or the scattered light coefficient. For example, the scattered light coefficient at a distance of around 50 pixels is $10^{-5.993}$. At a distance of about 2 pixels, the scattered light coefficient is $10^{-1.564}$, thus already about 4 orders of magnitude larger.--

Kindly replace the paragraph beginning at page 23, line 26, with the following:

-- Calibration of the scattered light correction:--

Kindly replace the paragraph beginning at page 24, line 7, with the following:

-- Whereby ΔR represents the total scattered light correction of an image point, $\Delta R_{AB1} \dots \Delta R_{AB6}$ the individual scattered light correction contributions of the individual analysis regions $AB_1 \dots AB_6$, and $G_1 \dots G_6$ the previously once determined weighting and calibration factors.--

Kindly replace the paragraph beginning at page 26, line 1, with the following:

-- Spectral correction:--

Kindly replace the paragraph beginning at page 26, line 11 (equation), with the following:

-- $(SP)_k = (IM)_k * (SP)_\gamma$,--

Kindly insert new paragraph beginning at page 26, line 30, as follows:

-- It will be appreciated by those skilled in the art that the present invention can be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The presently disclosed embodiments are therefore considered in all respects to be illustrative and not restricted. The scope of the invention is indicated by the appended claims rather than the foregoing description and all changes that come within the meaning and range and equivalence thereof are intended to be embraced therein.--

IN THE CLAIMS:

Kindly replace claims 1, 5, 7, 11, 13 and 19 as follows.

1. (Amended) Device for the pixel-by-pixel photoelectric measurement of a planar or flat measured object or object to be measured, comprising:

illumination means for illuminating the measured object or object to be measured with at least one essentially parallel light bundle at an angle of incidence of essentially $45^\circ + / - 5^\circ$;

a two-dimensional array of light converter elements for producing electric signals in response to light remitted by the measured object or object to be measured;

a tele-central imaging optics for imaging each point of the measured object or object to be measured onto the light converter element array at essentially the same observation angle of essentially 0° and with the same aperture angle of essentially maximally 5° ;

imaging means for imaging the measured object to be measured onto the two-dimensional array of light converter elements;

filters provided in the imaging light path for wavelength selective filtering of the measurement light impinging on the light converter elements;

signal processing means for processing the electrical signals produced by the light converter elements and for converting them into corresponding digital raw measured data; and

data processing means for processing of the raw measured data into image data representing colors of the individual pixels of the measured object.

5. (Amended) Device according to claim 3, wherein the blend filter is color neutral.

7. (Amended) Device according to claim 6, wherein the blend filter is positioned at least one of at and on the Fresnel lens.

11. (Amended) Device according to claim 10, wherein the video camera is a black and white camera and the filter means include a set of bandpass filters constructed as interference filters for the wavelength-selective filtering of the measuring light impinging on the light converter elements, and drive means for selectively moving the bandpass filters into the imaging light path.

13. (Amended) Device according to claim 11, wherein about 16 bandpass filters of about 20nm bandwidth each are provided which essentially cover the spectral range of 400-700nm.

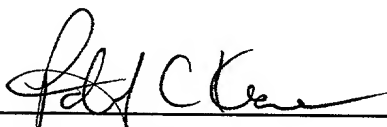
19. (Amended) Device according to claim 18, wherein the color-selective beam splitter arrangement splits the measuring light into about 16 spectral ranges of about 20nm bandwidth each, which essentially cover the spectral range of 400-700nm.

REMARKS

These amendments were made to place the application in a more suitable form prior to examination. Favorable consideration is respectfully requested.

Respectfully submitted,

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Date: December 7, 2001

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Page 2, Paragraph Beginning at Line 22

It is [therefor] therefore a further important object of the present invention to provide means for correcting the mentioned interference effects so that the measured data have the precision required for colorimetric applications.

Page 2, Paragraph Beginning at Line 31

Preferred embodiments of the invention will be described in the following by way of example only and with reference to the drawings, wherein:

Figure 1 is a schematic illustration of a first embodiment of the measurement device in accordance with the invention;

Figure 2 is a schematic sketch of a spectral video camera of a second embodiment of the measurement device in accordance with the invention;

Figure 3 is a sketch illustrating the geometric rectification of the data of the measured object;

Figure 3A is an enlarged portion of Figure 3;

Figures 4 and 5 show two sketches for illustration of the reflection correction;

Figure 6 is a sketch for illustration of the scattered light correction;

Figure 6A shows an enlarged portion of Figure 6;

Figures 7A and 7B show two test images with respectively one special calibration element;

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Figure 8 is a test image with a special scattered light element;

Figure 8A shows the scattered light element of Figure 8 in an enlarged illustration;

Figure 9 is a diagram for the illustration of the calculation of scattered light coefficients [and]; and

Figure 10 is a schematic summary of all correction measures.

Page 4, Paragraph Beginning at Line 18

The two flash light sources 4 and 5 are respectively positioned at the focal point of the illumination lenses 42 and 52, so that the measured object M is illuminated with two parallel beam bundles 44 and 54. The positioning is selected such that the angles of incidence $[\alpha]$ of the two parallel beam bundles are essentially $45^\circ + /-5^\circ$ to the optical axis of the imaging optics or to the normal 31 of the measured object M. The geometric conditions defined in international standards for the color measurement are thereby complied with.

Page 13, Paragraph Beginning at Line 3

The position deviations $[\Delta] \Delta X$ and $[\Delta] \Delta Y$ relative to the normal positions (points 301-309) are determined for each of the nine reference points 311-319 as is apparent from Figure 3a. In the next step, the position deviations for each individual image point of the whole test image are calculated by interpolation from the position deviations of the nine

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reference points. According to experience, the position deviations of closely adjacent image points are not very different. Thus, according to one aspect of the invention, several, for example 8x8 adjacent image points, are respectively combined into a geometry correction region and the position deviations are calculated only for those geometry correction regions. If one assumes a total of 480 x 640 image points, this results in about $60 \times 80 = 4,800$ regions. The (calculated) position deviations $[\odot] \Delta x$ and $[\odot] \Delta y$ of those 4,800 geometry correction regions are then saved in a geometry correction table. A portion of an exemplary geometry correction table is illustrated in Table 3 ($[\odot] \Delta x$ and $[\odot] \Delta y$ values are arbitrary).

Page 13, Paragraph Beginning at Line 16

For the geometric correction of the measured object, the geometry correction region to which an image point belongs is determined for each image point (by way of its image point coordinates) and the position deviation $[\odot] \Delta x$ and $[\odot] \Delta y$ for the respective geometry correction region obtained from the geometry correction table. The actual correction is then carried out in the manner already known in that the measured value of the respective image point is replaced by the measured value of the image point displaced by the position deviation (or by a value interpolated from the surrounding points for non-integer pixel spacings).

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Page 13, Paragraph Beginning at Line 23 (Table 3)

Table 3

| Region Number | Image Points | [C] Δx (in pixel) | [C] Δy (in pixel) |
|---------------|-------------------|---------------------------|---------------------------|
| 1 | x1...x8, y1...y8 | [3,25] 3.25 | -5.75 |
| 2 | x9...x16, y1...y8 | 3.2 | -5.7 |
| And so on | and so on | and so on | and so on |

Page 17, Paragraph Beginning at Line 17

The scattered light correction for each image point subtracts from the brightness value (remission value) of the respective image point the distance dependent brightness contribution of all image points surrounding the image point. The brightness contribution [C] $\Delta R_{i,j}$ received by an image point i from an image point j is calculated as [C] $\Delta R_{i,j} = k_{i,j} * R_j$. R_j is thereby the remission value of the image point j, and $k_{i,j}$ is a coefficient depending on the distance between the image points i and j, which of course must be determined beforehand. For an arrangement of N*M image points, which are numbered from 1-N*M, the contribution of the surrounding points is calculated as follows for each individual image point i:

Page 17, Paragraph Beginning at Line 26

The scattered light corrected remission value R'_i is $R_i - [C] \Delta R_i$. As is easily apparent, $(M*M)^2$ coefficients and a corresponding number of multiplications and additions

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are required for the calculation of the corrections. For 300,000 image points, the required calculation effort would be gigantic and completely impractical as already mentioned.

Page 21, Paragraph Beginning at Line 11

Scattered light correction of individual image regions:

Page 21, Paragraph Beginning at Line 17

Determination of the scattered light correction coefficients:

Page 23, Paragraph Beginning at Line 1

By way of numerous test measurements with scattered light elements of different size, it was found that the scattered light influence decreases at a double logarithmic scale at least in some sections and also overall approximately linear with distance. Figure 9 graphically illustrates in a double logarithmic scale an exemplary relationship between scattered light and image point distance measured by way of 8 scattered light elements. The abscissa shows the distance in pixel units, the ordinate the negative logarithm of the relative scattered light influence or the scattered light coefficient. For example, the scattered light coefficient at a distance of around 50 pixels is $10^{-5.993}$. At a distance of about 2 pixels, the scattered light coefficient is $10^{-1.564}$, thus already about 4 orders of magnitude larger[!].

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Page 23, Paragraph Beginning at Line 26

Calibration of the scattered light correction:

Page 24, Paragraph Beginning at Line 7

Whereby $[\odot] \Delta R$ represents the total scattered light correction of an image point,
 $[\odot] \Delta R_{AB1} \dots [\odot] \Delta R_{AB6}$ the individual scattered light correction contributions of the
individual analysis regions $AB_1 \dots AB_6$, and $G_1 \dots G_6$ the previously once determined
weighting and calibration factors.

Page 26, Paragraph Beginning at Line 1

Spectral correction:

Page 26, Paragraph Beginning at Line 11 (equation)

$$(SP)_k = (IM)_k * (SP)_{\gamma \rightarrow}$$

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Marked-up Claims 1, 5, 7, 11, 13 and 19

1. (Amended) Device for the pixel-by-pixel photoelectric measurement of a planar or flat measured object or object to be measured, comprising:

illumination means for illuminating the measured object or object to be measured with at least one essentially parallel light bundle at an angle of incidence of essentially $45^{\circ} \pm 5^{\circ}$;

a two-dimensional array of light converter elements for producing electric signals in response to light remitted by the measured object or object to be measured;

a tele-centrical imaging optics for imaging each point of the measured object or object to be measured onto the light converter element array at essentially the same observation angle of essentially 0° and with the same aperture angle of essentially maximally 5° ;

imaging means for imaging the measured object to be measured onto the two-dimensional array of light converter elements;

filters provided in the imaging light path for wavelength selective filtering of the measurement light impinging on the light converter elements;

signal processing means for processing the electrical signals produced by the light converter elements and for converting them into corresponding digital raw measured data; and

data processing means for processing of the raw measured data into image data representing [the colours] colors of the individual pixels of the measured object.

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Marked-up Claims 1, 5, 7, 11, 13 and 19

5. (Amended) Device according to claim 3, wherein the blend filter is [colour]
color neutral.

7. (Amended) Device according to claim 6, wherein the blend filter is
positioned at [or on] least one of at and on the Fresnel lens.

11. (Amended) Device according to claim [9] 10, wherein the video camera is a
black and white camera and the filter means include a set of bandpass filters constructed as
interference filters for the wavelength-selective filtering of the measuring light impinging
on the light converter elements, and drive means for selectively moving the bandpass filters
into the imaging light path.

13. (Amended) Device according to claim 11, wherein about 16 bandpass filters
of about 20nm bandwidth each are provided which essentially cover the spectral range of
400-700nm.

19. (Amended) Device according to claim 18, wherein the [colour-selective]
color-selective beam splitter arrangement splits the measuring light into about 16 spectral
ranges of about 20nm bandwidth each, which essentially cover the spectral range of
400-700nm.

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Marked-up Abstract

-- The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means [(3,21)] for the imaging of the measured object [(M)] onto a two-dimensional CCD image sensor [(22)], filter means [(66)] provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means [(23)] for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured [(71)], as well as data processing means [(7)] for the processing of the raw measured data into image data [(72)] representing the colors of the individual image elements of the measured object. Furthermore, illumination means [(4,41-43; 5,51-53)] are provided which include a Fresnel lens [(42:52)], which illuminate the measured object [(M)] with at least one essentially parallel light bundle under an angle of incidence [$\dot{\alpha}$] of essentially $45^{\circ} \pm 5^{\circ}$. The projection means which include at least one tele-lens [(3)] constructed as a Fresnel lens, are constructed as tele-central imaging optics [(3,21)], which image each point of the measured object [(M)] under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle [$\dot{\alpha}$] of essentially maximally 5° onto the light converter element array [(22)]. The data processing means [(7)] carry out extensive correction measures.

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Abstract

The device for the pixel-by-pixel photoelectric measurement of a planar measured object includes projection means for the imaging of the measured object onto a two-dimensional CCD image sensor, filter means provided in the imaging light path for the wavelength selective filtering of the measuring light impinging on the image sensor, signal processing means for the processing of the electrical signals produced by the image sensor and for the conversion thereof into corresponding digital raw measured, as well as data processing means for the processing of the raw measured data into image data representing the colors of the individual image elements of the measured object. Furthermore, illumination means are provided which include a Fresnel lens, which illuminate the measured object with at least one essentially parallel light bundle under an angle of incidence of essentially $45^{\circ} \pm 5^{\circ}$. The projection means which include at least one tele-lens constructed as a Fresnel lens, are constructed as tele-central imaging optics, which image each point of the measured object under essentially the same angle of observation of essentially 0° and with essentially the same aperture angle of essentially maximally 5° onto the light converter element array. The data processing means carry out extensive correction measures.